THE UNIVERSITY OF UTAH

2 October 1990

Ms. Diane Neilson
Utah Div. of Oil, Gas, and Mining
355 West North Temple
3 Triad Center, Suite 350
Salt Lake City, UT 84180-1203

Dear Diane:

As promised, I have attached a copy of a research proposal funded by the University of Utah Research Committee to study various factors that influence groundwater flow and solute transport in natural closed-desert-basin hydrologic systems similar to that found in the Pilot Valley, Utah.

I hope to develop new insight into the nature of the groundwater flow system by exploiting the way that groundwater flow modifies the chemical and isotopic signature of water samples obtained within the flow system. To this end, a suite of water samples will be collected from (1) high-elevation springs issuing from bedrock, (2) low-elevation springs issuing near the break-in-slope of surface topography at the playa margin, and (3) from piezometers installed by previous workers and in the course of the current project. Preliminary review of chemical analyses performed on water samples collected from springs and existing wells is underway and will be completed in the next few weeks. We expect that these results will provide a basis for establishing optimal locations for collecting the water samples to be submitted for isotopic analyses (Oxygen-18, Deuterium, and Tritium).

Our existing funds and equipment restrict us to shallow drilling depths (maximum depth is 45 feet) within regions of the playa that readily support conventional four wheel vehicles. In order to obtain the water samples and lithologic information needed to properly characterize the chemical and groundwater conditions within the basin we need to use a drill-rig mounted on a vehicle with tracks or balloon tires. If possible, such a rig should also have the capability to drill to depths in excess of 100 feet; both on the playa and on the adjacent alluvial fan deposits (the auger rig on loan from the UGMS is unable to penetrate to any significant depth in materials other than the silts and clays found within the playa). Several suitable rigs are reported to be available in the Salt Lake Valley and I am in the process of obtaining cost estimates.

Department of Geology and Geophysics

College of Mines and Earth Sciences
717 W. C. Browning Building
Salt Lake City, Utah 84112-1183
(801) 581-7162

FAX U of U Mines and Earth Sciences
(801) 581-5560

As we discussed on the telephone, I am soliciting the funding needed to contract the drilling services and to subsidize the costs of piezometer construction and sample analyses. A preliminary estimate suggests that about $20,000.00 would enable this project to reach a point where realistic inferences regarding the character of the Pilot Valley flow system can be made. Preliminary discussions with the University administration suggest that if the State of Utah were to provide a $12,000.00 grant of non-Federally sourced funds (with 10% indirect costs charged by the U of U and 38% considered to be a legitimate matching contribution made by the U of U), then I could apply to the USGS Water Resources 105 Program for matching funds in the amount of about $16,000.00 (with 48% indirect costs charged by the U of U). The funds available for research would then be about $19,000.00 (the grant total of $28,000.00 less the indirect costs of $9,000.00).

The added insight gained by augmenting the ongoing research with additional drilling and sampling is expected to provide an integrated interpretation of the geochemical and hydrologic systems found in a closed desert basin that will, in turn, assist the USGS and others in their studies of the processes that control development of salt crusts in desert basins.

If you have any queries please feel free to contact me at your convenience. My phone number on campus is 581-3864. Thank you for considering this solicitation.

Sincerely,

Craig B. Forster
Research Assistant Professor

APPENDIX A
Faculty Grant Proposal

Research Project _X_ or Creative Project ____

Investigator: **Date:** March 21, 1990

Name (typed): Craig B. Forster Soc. Sec. No: 529-59-2737

Signature: ________ Phone No: 3864

Campus Address: 719 W.C. Browning Building Mail Code: 1183

Department: Geology & Geophysics Home Dept. No: ________

Faculty Rank: Reasearch Assistant Professor

Department Chair: Name (typed): Dr. Francis Brown

Signature: David S. Chapman fr. FHR

Project Title: A Field-Based Study of the Likelihood for Salinity-Driven Free Convection Beneath the Pilot Valley Play, Utah-Nevada

Project Short Title (30 Characters or less): Free Convection Beneath Playas

Duration of Activity: 1 Year **Amt. Funds Requested:** $3920

Abstract: This summary should be understandable by informed scholars outside the investigator's field. Use provided space only!

Previous workers have proposed that contrasts in fluid density caused by evaporative distillation of shallow groundwater within playas (salt flats) can cause salinity-driven free convection beneath the playa. Field-based confirmation of the presence (or absence) of free convection is required to refine and validate conceptual and numerical models of groundwater flow and solute transport in this and similar environments. The necessary data can be obtained by collecting a set of groundwater samples from a variety of depths and at several locations within the Pilot Valley playa located on the Utah-Nevada border. Rates of vertical groundwater flow will be estimated by comparing the resulting concentration-depth profiles, obtained for a variety of chemical and stable isotope species, with one another and with a series of theoretically-derived concentration profiles. If it can be shown that groundwater velocities exceed 10^{-11} m s^{-1}, then it is likely that one or more salinity-driven free-convection cells may exist beneath the playa.

***Does project include: ___Animals ___Human Subjects ___Radioisotopes?
Does budget include any computer equipment or software? ___

APPENDIX B

Budget

1. Supplies:

a. Piezometer pipe $ 270.00
450 ft. @ $0.60 per ft.

b. Piezometer completion $ 540.00
materials: 36 @ $15.00

c. Fuel for auger rig and $ 200.00 Total $ 1010.00
misc. suplies (incl. hand pump and sample bottles)

2. Equipment:

a. Hand auger with extensions $ 380.00
to 4 meters length

b. Electrical conductance probe $ 600.00 Total $ 980.00

2.1 Sample Analyses - Chemical & Isotope
c. 12 samples @ $140.00 $ 1680.00 Total $ 1680.00

Justification for equipment valued in excess of $1,000:

3. Travel:

a. Domestic $ 250.00
Department 4x4 Vehicle
500 miles @ $0.50 per mile

b. Foreign (limited funds) $ ______ Total $ 250.00

Justification for travel expenses:

Collection of field data requires at least 2 trips to the Pilot Valley

4. Assistance (Hourly or Work-Study Wages) $ 0.00

Employee Benefits $ ______ Total $ 0.00
Please indicate the kind of work assistants will do.

5. Creative Project Documentation: Total $ ______

Grand Total $ 3920.00

****NOTE:** If another category is needed, please cross out one not being used and list desired category.

III. A FIELD-BASED STUDY OF THE LIKELIHOOD FOR SALINITY-DRIVEN FREE-CONVECTION BENEATH THE PILOT VALLEY PLAYA, UTAH-NEVADA

INTRODUCTION

Duffy and Al-Hassan (1988), using the results of numerical modeling studies, suggest that salinity-driven groundwater flow systems may be found beneath playas (salt flats) located in closed desert basins. A conceptual model of the system that they envisage is shown in Figure 1 where evaporation of groundwater at the playa surface (the sole mechanism for discharge of water from the basin) serves to concentrate dissolved constituents in shallow groundwater. The resulting increase in fluid density near the water table is presumed to cause a buoyancy-driven downflow of groundwater in the central region of the playa and upflow along a freshwater-saltwater interface located beneath the playa margin (Figure 1). In addition, a brine wedge (a distinct region of saline groundwater below the valley floor) is expected to form as groundwater movement transports solutes dissolved in the groundwater through the system.

The rate of evolution, extent, and chemical character of a brine wedge will be dictated, in large part, by the processes controlling solute transport. If groundwater velocities in a postulated free-convection cell are less than about 10^{-11} m s^{-1} (0.0003 m per year) solute transport is dominated by chemical diffusion away from the water table. Where fluid velocities exceed this value, advective transport dominates. Because vertical variations in the concentration of solutes dissolved in the groundwater are expected to reflect the dominant process controlling transport, I propose to collect groundwater samples from a variety of depths beneath the Pilot Valley playa. Laboratory analyses of solute and stable isotope concentrations in the samples will provide a basis for inferring the range of groundwater velocities required to produce the observed concentration-depth profiles.

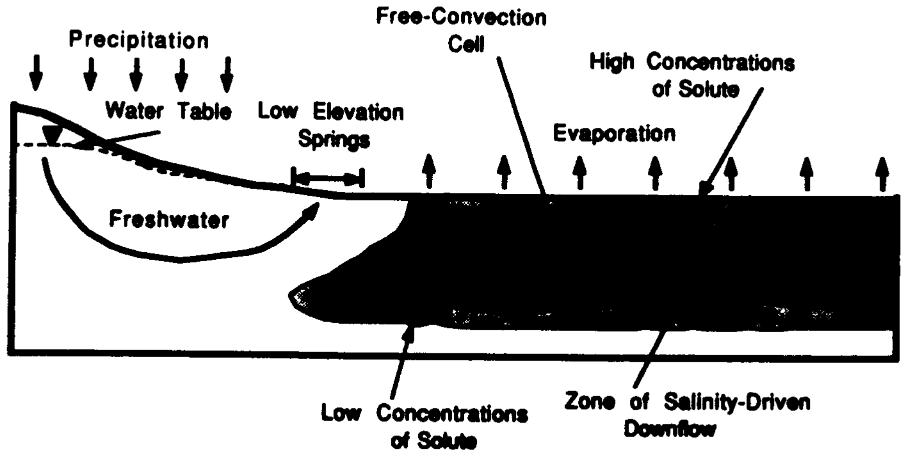

Figure 1. Conceptual model of groundwater flow and solute transport beneath a playa. Vertical exaggeration is approximately 10:1. The location of the brine wedge is indicated by the stippled region.

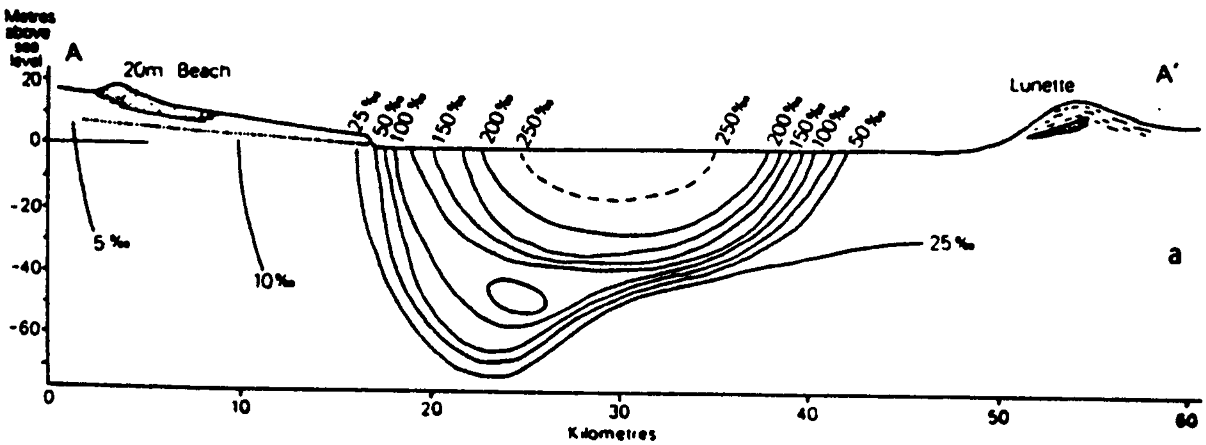

Figure 2. Dissolved-solids concentration of brine beneath the Lake Frome playa, Australia expressed as weight per mil (‰). From Bowler, 1986.

The proposed study appears to be the first attempt to obtain the field data needed to assess whether or not a salinity-driven free-convection cell might control solute transport beneath a playa. Although a saltwater-freshwater interface indicates the presence of a brine wedge beneath the margin of the Pilot Valley playa (Duffy and Al-Hassan, 1988), insufficient information is available to establish if the flow system inferred from theoretical studies might exist in the field. A brine wedge located beneath a playa found in Lake Frome, Australia (Figure 2) is more completely characterized (Bowler, 1986); however, little effort has been made to establish the dominant mechanism for solute transport.

Obtaining a better understanding of the conditions promoting salinity-driven groundwater flow beneath a playa will help refine conceptual models proposed to explain groundwater flow and solute transport in a variety of geologic environments. For example, Bethke (1988) suggests that saline groundwaters originating in a paleo playa environment were incorporated in a regional-scale groundwater circulation system and played an important role in the genesis of ore deposits found at Creede Caldera, Colorado. Although potentially important, the impact of salinity-driven flow on the timing and character of mineralization has yet to be evaluated. An important goal of this study is to obtain the information needed to begin validating regional-scale numerical models that attempt to represent the buoyancy-driven groundwater flow that results from salinity-derived density variations.

ESTIMATING RATES OF FLUID FLUX AND DEPTHS OF SOLUTE TRANSPORT

Using an analytical solution to the 1-dimensional transport equation (including advection, diffusion, and mechanical mixing within a vertical column of porous media) provided by Ogata and Banks (1961) I have estimated the concentration profiles that might be expected beneath the playa. A constant concentration of the species of interest (e.g., Cl^-) is specifed at the upper boundary ($C = C_0$) while the lower boundary is held at a concentration of zero. The impact of chemical reactions on solute concentrations are not considered and the initial concentration of the species of interest is assumed to be zero throughout the sediment column. This configuration corresponds nicely to the field situation where evaporation of groundwater within the playa leads to elevated concentrations of soluble species and enrichment in the concentrations of heavier stable isotopes at the water table.

Data presented by Lines (1979) indicates that a strong chemical signal will be provided because total dissolved solids concentrations exceed 300 g per litre (Figure 3) and Cl^- concentrations exceed 170 g per litre. In addition, fractionation of light stable isotopes of oxygen and hydrogen by evaporation under non-equilibrium conditions (lighter isotopes are transported away from the region of evaporation) can produce concentration deviations in excess of 4‰ for H_2O^{18} and 10‰ for HDO. Because these variations are much larger than uncertainties inherent in the analytical procedures; ± 0.2‰ for oxygen-18 and ± 2‰ for deuterium a strong isotopic signal should be present at the water table.

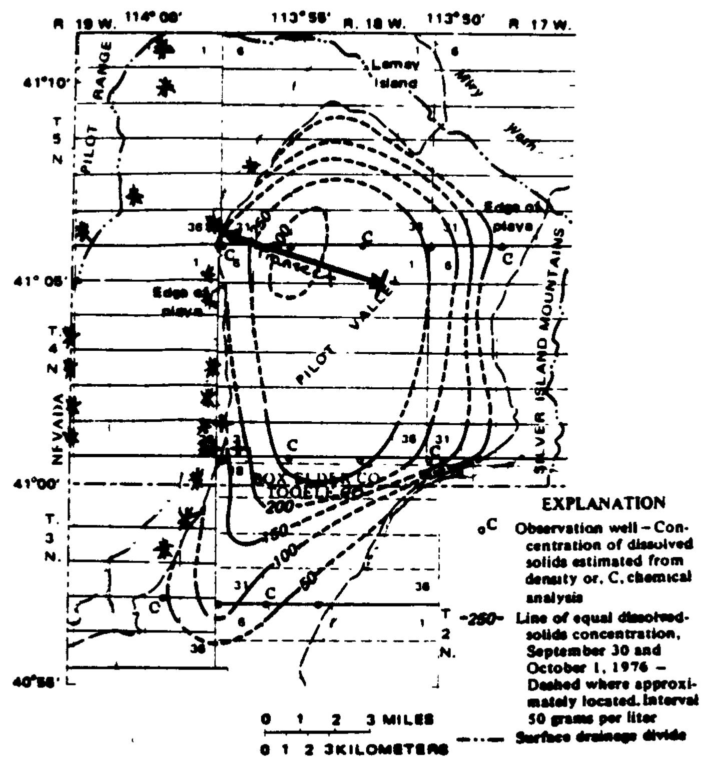

Figure 3. Dissolved-solids concentration of brine in the shallow-brine aquifer in Pilot Valley, fall of 1976. The locations of groundwater springs are indicated with *'s and the piezometer nests installed by Duffy and co-workers are indicated with +'s. The proposed sampling transect is also indicated. From Lines (1979).

The results of a series of calculations are shown in Table 1. Numerical simulations of two-dimensional coupled fluid flow and solute transport in a vertical section representing the Pilot Valley (Duffy and Al-Hassan, 1988) suggest that 10^{-8} m s^{-1} is a reasonable upper limit for v_z. In cases where v_z is less than about 10^{-11} m s^{-1}, chemical diffusion dominates the transport of solutes. Although there is some uncertainty in estimating the time when the evaporation process began to promote elevated solute concentrations at the water table, a time of 10,000 years is assumed (geologic evidence suggests an upper limit of 30,000 years). A median value for the coefficient of hydrodynamic dispersion D_z (representing the processes of both chemical diffusion and mechanical mixing in the porous medium) was selected (5×10^{-10} m^2 s^{-1}).

Where computed values of the normalized concentration C/C_o equal 1.0, a uniform concentration profile (with concentration = C_o) is expected at shallower depths than the sample location (Table 1). Where values of C/C_o equal zero, the indicated depth has yet to be reached by the downward moving solute front. At intervening depths, the character of the concentration-depth profile will reflect the rate of vertical fluid flux. A highly non-linear profile is typical. It is apparent from the results shown in Table 1 that a 1 m sampling depth is too close to the solute source to provide the information needed to estimate fluid velocities. Collecting samples at a depth of 10 m; however, may assist in discriminating between diffusion-dominated transport and the influence of slow circulation in a salinity-driven free-convection cell. Where fluid velocities are less than 10^{-11} m s^{-1}, a non-uniform concentration-depth profile is anticipated at depths shallower than 10 m. Where velocities exceed 10^{-11} m s^{-1}, a uniform concentration equal to the solute concentration at the water table is anticipated. Although a distinction might be made between diffusive versus advective transport with samples collected at depths shallower than 10 m, sample depths on the order of 100 m are required to attempt quantifying vertical groundwater velocities. The oxygen-18 and deuterium content of groundwater is considered to be a conservative property that is unaffected by physiochemical processes that influence the concentration of dissolved solids in groundwater. As a consequence, in diffusion-dominated situations, the stable isotope front should be found at shallower depths than the associated solute fronts. This result provides an important tool for discriminating between diffusive and advective transport.

TABLE 1. Estimates of Normalized Concentration C/Co as a Function of Fluid Velocity and Sampling Depth Assuming a Time Since Initiation of Solute Transport =10,000 years

DEPTH (m)	Diffusion Alone	$v_z = 10^{-11}$ m s^{-1}	$v_z = 10^{-10}$ m s^{-1}	$v_z = 10^{-9}$ m s^{-1}	$v_z = 10^{-8}$ m s^{-1}
1	0.98	1.00	1.00	1.00	1.00
10	0.57	1.00	1.00	1.00	1.00
100	0.00	0.00	1.00	1.00	1.00

APPROACH

I propose to obtain vertically-distributed groundwater samples from a small number of sites within the Pilot Valley playa as a first step in estimating the potential for estimating vertical fluid velocities beneath a playa. Groundwater samples will be collected by installing PVC pipes with short intake screens (piezometers) at depths up to 10 m beneath the playa surface and collecting samples of groundwater that enters each piezometer. A peizometer nest comprises a group of piezometers installed at various depths at the same location. Analyzing the samples obtained from each nest provides an opportunity to obtain a preliminary indication of vertical variations in the concentrations of a variety of chemical species and stable isotopes.

The hydrology and geology of the Pilot Valley playa (located 190 km east of Salt Lake City) and other playas in the Western U.S.A. (including the Bonneville Salt Flats) have received considerable attention in the past (Nolan, 1928; Motts, 1965; Motts, 1970a and 1970b; Stephens and Hood, 1973; Turk, 1973; Lines, 1979; Duffy and Al-Hassan, 1988). This background information will be exploited to advantage when designing and implementing the proposed study.

Processes that might complicate interpretations of the chemical and isotopic data include: (1) repetitive cycles of playa formation that may cause nonuniform variations in solute and isotopic concentrations at the water table, (2) longterm spatial and temporal variations in evaporation rates that may yield changes in solute and isotopic concentrations at the water table, and (3) rock-water interactions (e.g., dissolution or precipitation of evaporite minerals) that modify solute concentrations (but not isotope concentrations). Despite these added complexities, the preliminary analyses outlined in this proposal suggest that it is worth collecting vertically-distributed samples of shallow groundwater to assess whether or not a larger scale investigation should be initiated.

METHODOLOGY

TASK 1. Piezometer Installation: Piezometers will be installed by drilling to a series of pre-determined depths (or as deep as practicable) then installing 3.8 cm diameter PVC pipe in each auger hole with a sand pack and filter screen (0.3 m long) providing access to the adjacent formation at the bottom of each pipe. Shallow holes (1 to 3 meters deep) will be drilled using a hand auger (to be purchased using funds granted for this study). Deeper holes (up to 10 meters deep) will be drilled with a trailer-mounted auger on loan from the Utah Geological and Mineral Survey (this rig is currently unable to penetrate beyond depths of 10 m). All holes will be backfilled with a mix of bentonite and chemically inert fine-grained material..

My goal is to complete 8 piezometer nests that each comprise three holes drilled to depths of about 1, 3, and 10 meters, and two nests that each comprise up to 6 holes completed at various depths to about 10 meters. The first several piezometer nests will be located ~~along a transect chosen~~ to obtain concentration-depth profiles along a transect that will show the transition from relatively low fluid density to the maximum fluid density indicated for the playa (maximum density corresponds to the maximum concentration of dissolved solids shown in Figure 3). Variations in electrical conductance and field estimates of Cl^- and SO_4^{-2} concentrations observed in each piezometer nest will be used to estimate the lateral and vertical variaions in dissolved solids and solute concentrations. These data will, in turn, aid in selecting the locations of subsequent piezometer nests. Every effort will be made to identify and instrument the most likely locations for downflow in one or more salinity-driven free-convection cells. The final 6-hole piezometer nests will be installed at the most likely locations for downflow. The bulk of this work will be carried out in late September, 1990 when the playa surface is sufficiently dry to provide vehicular access.

TASK 2. Collection of Groundwater Samples: Groundwater samples will be collected from (1) a subset of the piezometers installed in this program, (2) several piezometers installed in previous studies, and (3) from springs located on the flank of the Pilot Range mountains (Figure 3). Standard techniques will be used to collect, transport, and preserve the samples for both chemical and isotopic analyses. Because water levels in the piezometers will be close to the ground surface (depths to water are generally less than 1 m), groundwater samples are easily extracted with a bailer or small hand pump. The P.I. and several of his assistants are well acquainted with the necessary procedures.

Because insufficient funding is requested to collect and analyze samples from all the possible sample locations, sample sites will be prioritized after completing all the piezometer nests. Cl^-, SO_4^{-2}, and electrical conductance will be measured in the field to define vertical and lateral variations in solute concentration. A Hach kit (available within the Department of Geology and Geophysics) will be used to obtain preliminary estimates of Cl^- and SO_4^{-2} at each sample location and electrical conductance will be measured with a portable electrical conductivity probe designed to obtain in-situ measurements in wells (to be purchased using funds granted for this study). A representative suite of samples should include two samples from the upper elevation springs (Figure 3) and two samples from the lower elevation springs. The remaining samples will be collected to provide analyses across the range of vertical chemical gradients observed in the field analyses. Analyses of spring waters are necessary in order to obtain estimates of background concentrations for each chemical species and each stable isotope to be used in inferring the dominant mechanisms controlling fluid flow and solute transport beneath the playa. Both chemical and stable isotope ~~analyses~~ samples will be sent to commercial laboratories for analysis. Species to be analyzed in each groundwater sample will include Na, K, Ca, Mg, Fe, Al, SiO_2, B, Li, Sr, HCO_3, CO_3, F, SO_4, TDS, pH, δO^{18}, and δD.

TASK 3. Data Analysis: The results of the analyses of the groundwater samples will be compiled and interpreted with a view to establishing the most likely mechanisms causing the observed lateral and vertical gradients (or lack of a gradient) in the concentration of each chemical species and stable isotope. Simple analytical models describing 1-dimensional solute transport by advection, dispersion, diffusion, and possibly chemical reactions (similar to those outlined in an earlier section) will be used to obtain the necessary insight. An assessment of the uncertainty inherent in each of the measured parameters will be incorporated in the final analysis.

ANTICIPATED RESULTS

The proposed study is expected to yield a preliminary understanding of the vertical variation in the concentration of several chemical species (including Cl, SO_4, Ca, Mg, Na, CO_3, and a number of trace elements) and stable isotopes oxygen-18 and deuterium in the sediments underlying the floor of the Pilot Valley playa. This information will be used to establish whether or not regions of relatively large vertical fluid flux (10^{-11} to 10^{-9} m s^{-1}) are likely beneath the Pilot Valley. If the vertical profiles of solute and isotope concentrations indicate the presence of significant vertical groundwater flow, then it seems plausible that the salinity- driven free-convection cell proposed by Duffy and Al-Hassan (1988) might exist beneath the valley floor. Otherwise, a different flow system must be proposed where diffusive transport controls the vertical variations in solute concentration.

The data set, and preliminary interpretations obtained in the proposed study, will form the basis for a proposal to be submitted to the National Science Foundation, or the U.S. Geological Survey, to obtain the funding needed to install additional sampling points and obtain a more detailed picture of the vertical concentration profiles. The detailed profiles will help to constrain numerical modeling studies proposed to explore the primary mechanisms thought to control basin-scale fluid flow and solute transport.

By conducting many of the field activities during the Geology & Geophysics summer field camp, undergraduate students enrolled in the course will gain hands-on experience in many aspects of hydrogeologic field investigations.

BUDGET

1. Supplies	
a. piezometer pipe 450 ft. @ $0.60 per foot	270.00
b. piezometer completion materials 36 @ $15.00	540.00
c. fuel for auger rig and misc. supplies (incl.hand pump for water sampling and sample bottles)	200.00
2. Equipment	
a. hand auger with extensions to 4 meters length	380.00
b. electrical conductance probe	600.00
2a. Sample Analyses	
a. chemical analyses 12 @ $90.00	1080.00
b. isotope analyses 12 @ $50.00	600.00
3. Travel	
a. Domestic	
Department 4x4 Vehicle	
2 trips with total 500 miles @ $0.50 per mile	250.00
4. Assistance	0.00
TOTAL	3920.00

PERSONNEL

The tasks outlined above will be carried out by the Principal Investigator (P.I.) with assistance from a number of volunteer personnel. Dr. Paul Jewell from the department of Geology and Geophysics is interested in studying the paleohydrology of lakes found in a variety of environments including those that were present prior to the development of the Pilot Valley playa. In addition, up to one dozen undergraduate students enrolled in the summer field camp offered by the Department of Geology and Geophysics will carry out a major portion of the field work over a 4 to 5 day period in late September. Erik Peterson (a M.S. student enrolled at Brigham Young University) and his major professor Dr. Alan Mayo are interested in assisting in the collection of field data that will help constrain the numerical modeling studies that Erik will perform as part of his thesis research. Doug Oliver (a M.S. student enrolled at Utah State University) is currently collecting hydraulic and chemical data from 3 test-well arrays on the margin of the Pilot Valley as part of his thesis research. Doug would like to include the areally distributed data provided by this project in his interpretation of the relationship between climate, topography, and subsurface hydrology in closed desert basins.

SCHEDULE

A one year project is proposed. An initial round of piezometer installation and water sampling will be carried out in the early summer of 1990 in order to confirm the magnitude of the chemical and isotopic signals. The bulk of the piezometer installation and water sampling activities will be completed in late September 1990. Chemical and isotopic analyses should be complete by January 1991. Data analysis and interpretation of the concentration-depth profiles will be completed the spring of 1991. The results of the study will be incorporated in a proposal for additional funding from an external agency and, if appropriate, a paper to be submitted to a suitable scientific journal.

REFERENCES

Bethke, P.M., 1988. The Creede, Colorado ore-forming system: A summary model. U.S. Geol. Surv. Open File Report 88-403.

Bowler, J.M., 1986. Spatial variability and hydrologic evolution of Australian basins: Analogue for Pleistocene hydrologic change and evaporite formation. Palaeogeography, Palaeoclimatology, Palaeoecology 54:21-41.

Duffy, C.J., and Al-Hassan, S., 1988. Groundwater circulation in a closed desert basin: Topographic scaling and climatic forcing. Water Resources Research 24(10):1675-1688.

Lines, G.C., 1979. Hydrology and surface morphology of the Bonneville Salt Flats and Pilot Valley Playa, Utah., U.S. Geol. Surv. Water Supply Paper 2057.

Motts, W.S., 1970a. Some geologic and hydrologic processes influencing playa development in the Basin and Range Province, in Geology and Hydrology of Selected Playas in Western United States. (Motts, W.S., ed.), Massachusetts University Press, p. 237-268.

Motts, W.S., 1970b. Results of test drilling and winter mapping programs on Coyote Playa, California, in Geology and Hydrology of Selected Playas in Western United States. (Motts, W.S., ed.), Massachusetts University Press, p. 108-136.

Nolan, T.B., 1928. Potash brines in the Great Salt Lake Desert, Utah, in Contributions to Economic Geology Part 1 -- Metals and Nonmetals except fuels (Loughlin, G.F., and Mansfield, G.R., eds.), U.S. Geol. Surv. Bull 795-B, pp 25-44.

Ogata, A., and Banks, R.B, 1961. A solution of the differential equation of longitudinal dispersion in porous media, U.S. Geol. Surv. Prof. Paper 411-A.

Stephens, J.C., and Hood, J.W., 1973. Hydrologic reconnaissance of Pilot Valley, Utah and Nevada, State of Utah Department of Natural Resources Tech. Publ. No. 41.

Turk, L.J., 1973. Hydrogeology of the Bonneville Salt Flats, Utah, Utah Geol. and Min. Surv. Water Resources Bull. No. 19.

IV. ADDITIONAL INFORMATION

1. CRAIG B. FORSTER - QUALIFICATIONS

Education

Ph.D. 1987, Geological Sciences, The University of British Columbia, Vancouver, Canada

M.Sc. 1979, Earth Sciences, The University of Waterloo, Waterloo, Canada

B.Sc. 1975, Geological Sciences, The University of British Columbia, Vancouver, Canada

Professional Record

1989 - present	- **Research Assistant Professor**, Dept. of Geology and Geophysics, Univ. of Utah
1986 - 1989	- **Assistant Professor**, Dept. of Geology, Utah State University
1982 - 1986	- **Research Assistant**, Dept. of Geol. Sci., University of British Columbia
	- **Hydrogeologist**, Nevin Sadlier-Brown Goodbrand Ltd., Vancouver, B.C.
1980 - 1982	- **Hydrogeologist**, Klohn Leonoff Consultants Ltd., Vancouver, B.C.
1979 - 1980	- **Research Associate**, Dept. of Earth Sciences, University of Waterloo
1976 - 1979	- **Research Assistant**, Dept. of Earth Sciences, University of Waterloo
	- **Hydrogeologist**, Stallsbergbolagen A.B., Sweden (seconded to Lawrence Berkeley Laboratories, California)
	- **Hydrogeologist**, Atomic Energy of Canada Ltd., Ottawa, Ontario, (seconded to Geological Survey of Canada, Ontario)
1975 - 1976	- **Hydrogeologist**, Golder Brawner and Associates, Vancouver, B.C.

Research Experience

More than a decade of studying the movement of groundwater through geologic materials has provided a wide range of research experience using laboratory and field methods to test the hydraulic character of porous or fractured rock and developing numerical models of fluid flow, heat transfer, and mass transport in geologic media. Current research draws on previous experience in modeling regional-scale hydrothermal systems and characterizing the hydraulics of fractured rock to develop a better understanding of the role of groundwater circulation in geologic processes. Specific topics include: (1) using data obtained during a recent scientific cruise in the East Pacific to constrain numerical modeling studies of free-convection in a sedimented ridge flank environment, (2) simulating the transient cooling of a pluton emplaced beneath high-relief topography in order to obtain insight into the spatial and temporal distribution of temperature and pressure within the mountain massif that, in turn, influence landform-controlled eipthermal ore deposits, and (3) using the results of field mapping and laboratory measurement of rock permeability to constrain numerical models developed to gain insight into the hydraulic character of fault zones and their impact on regional-scale flow systems.

Publications

Davis, E.E., Chapman, D.S., Forster, C.B., and H. Villinger, 1989. Heat-flow variations correlated with burried basement topography on the Juan de Fuca Ridge flank, Nature, v. 342, 533-537.

Forster, C.B., and L. Smith, 1989, The influence of groundwater flow on thermal regimes in mountainous terrain: A model study, Journal of Geophysical Research, 94(B7), 9439-9451.

Smith, L., Forster, C.B., and A.D. Woodbury, 1989, Numerical simulation techniques for modeling advectively-disturbed thermal regimes, presented at IUGG, Vancouver, B.C., August, 1988, (in press as an AGU Monograph).

Forster, C.B. and L. Smith, 1988. Groundwater flow systems in mountainous terrain: 1. Numerical modeling technique, Water Resources Research, 24(7), 999-1010.

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2. GRANT ACTIVITY

This is my first attempt to obtain funding for the project described in this proposal. This is my first request for a Faculty Grant at the University of Utah.

3. CURRENT FUNDING

A. Title: Dynamical Anlaysis of Hydrologic Systems in the Mountains and Lowlands of Closed Basins

Participation: Co-Investigator with C.J. Duffy (P.I.), Civil & Environmental Engineering, Utah State University and S. Williams, Dept. of Applied Mathematics, Utah State University

Agency: U.S. Geological Survey and Utah Water Research Laboratory

Amount: $100,000 for period 7/1/88 to 6/30/90

B. Title: Hydrothermal Circulation in a Sedimented Ridge Flank Environment

Participation: P.I. with D. S. Chapman, Dept. of Geology & Geophysics, Univ. of Utah, E.E.Davis, Geol. Survey of Canada, Pacific Geoscience Centre, and M.J. Mottl, Dept. of Oceanography, Univ. of Hawaii

Agency: National Science Foundation (Oceanography & Marine Geology)

Amount: $160,000 for period 7/1/89 to 6/30/91.